TDS-87-03

Evaluation of the FREQ7PE Freeway Traffic Simulation Program

Ontario

Ministry of Transportation

Research and Development Branch

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Technical Report Documentation Page

Evaluation of the FREQ7PE Freeway Traffic Simulation Program

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Abstract:	The FREQ7PE freeway traffic simulation program was developed at the University of California. The objective of this study was to evaluate the program's ability to simulate the actual freeway system operating conditions of the Queen Elizabeth Way in Mississauga. It was concluded that FREQ7PE is capable of providing a reasonable approximation of the existing speeds on the eastbound Q.E.W. between Highway 403 and Highway 427.
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Attached herewith is a copy of the report "Evaluation of the FREQ7PE Freeway Traffic Simulation Program".

The report was prepared by McCormick Rankin and Associates at the request of the Ministry of Transportation. The objective of the research project described in this report was to evaluate the FREQ7PE Freeway Traffic Simulation Program's capability to simulate the actual freeway system operating conditions on the Queen Elizabeth Way in Mississauga.

The analyses suggest that FREQ7PE is capable of providing a reasonable approximation of the existing speeds in the study area.

We hope that you will find our research work useful to you and your staff.

Sincerely yours,

E.R. Case
Manager
Traffic and Decision Systems Office

Encl.

TDS-87-03

Evaluation of the FREQ7PE Freeway Traffic Simulation Program

D.R. Blay
McCormick Rankin & Associates

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EVALUATION OF THE FREQ7PE SIMULATION PROGRAM

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1. INTRODUCTION

1.1 BACKGROUND

Considerable inefficient use of a freeway results when the traffic demand exceeds the capacity of the facility. The by-products of excessive demands are:

- increased travel time,
- less reliable service,
- higher accident rates,
- greater fuel consumption, and
- increased vehicle emissions.

The traditional solution to these demand problems has been to increase the capacity of the facility. These traditional solutions are usually very expensive, often disruptive to the natural and social environment, and encourage further growth in travel demand.

In an effort to determine alternate solutions to the excess traffic demand problems, the Ministry of Transportation and Communications has initiated on-going programs for operational improvements on freeways. These alternate programs include the implementation of Freeway Traffic Management Systems (F.T.M.S.) as well as reconstruction.

As the state-of-the-art advances, the Ministry is increasingly turning to traffic flow simulation programs to predict the results of such improvements and to evaluate alternative strategies before implementation.

One of the most widely known and used freeway simulation program is the FREQ macroscopic model developed at the University of California. The Ministry, after obtaining the advanced version of the FREQ7PE program (which included certain features of the latest FREQ8PE version), and enhancing the program to include options such as alternative weaving methods, weave adjustment factors and merging sub-routines, decided to undertake a study to determine the programs performance in actual freeway simulation.

The essential pre-requisite for this undertaking is a detailed knowledge of traffic flows, trip origins and destinations and accurate speed profile data. Based on a search by the Traffic and Decision Systems Research Office, Research and Development Branch of the Ministry, the best source of this data was the eastbound section of the Q.E.W. located within the City of Mississauga.

1.2 STUDY OBJECTIVE

The objective of this study is to carry out an evaluation of FREQ7PE's capability to simulate the actual freeway system operating conditions, on the Q.E.W. in Mississauga.

In undertaking this evaluation, the objective was not to analyze the formulation of the programs but to determine:

- the capability that the program has to replicate conditions that exist for the eastbound lanes of the Q.E.W. between Ford Drive and Hwy. 427,
- the ease of use of the models user manual,
- the ease of inputting data,
- the ease of interpreting the output data, and
- the time/cost required to complete each computer run.

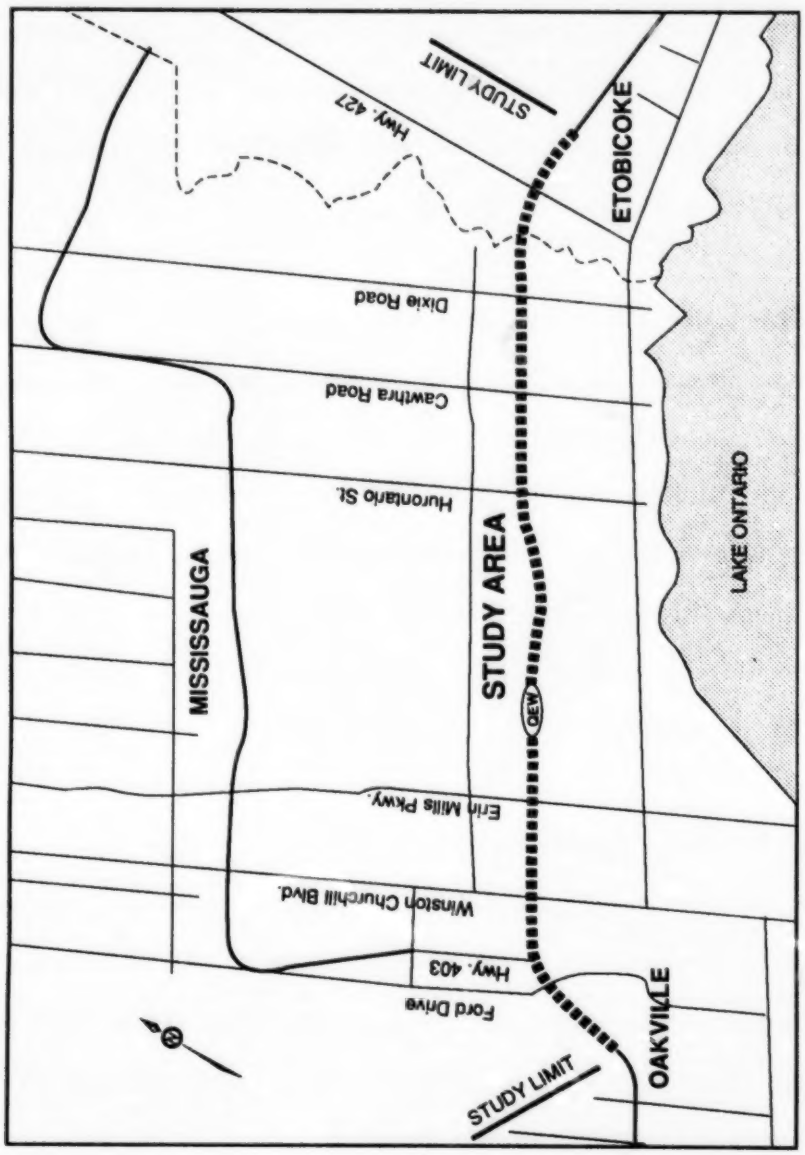


Figure 1.0/ Study Area

2. FREQ7PE SIMULATION PROGRAM

2.1 GENERAL DESCRIPTION

The FREQ7PE model is a deterministic macroscopic decision model of a freeway corridor and has been developed primarily for the evaluation of priority entry and normal entry control on a directional freeway. This model also has the capability to evaluate design improvements with or without freeway entry control. (The evolution of this model is graphically illustrated in Figure 2.1).

The user selects the type of entry control, the objective function and the operational constraints. The program simulates the system, implements a control strategy through a linear programming optimization and predicts a time stream of impacts and traveller responses due to the interaction between ramp control and response. The impact assessment includes travel time, fuel, emissions and noise. The demand forecasting includes the capability for spatial and modal traveller response.

2.2 DATA INPUT REQUIREMENTS

The major data requirement for this program is a set of origin-destination (O-D) tables for each interval of time. An O-D table gives for each input section along the freeway (mainline or on-ramp origin) the number of vehicles that are travelling to each destination along the freeway (off-ramp or mainline destined).

A 15 minute time slice interval is usually recommended for constructing O-D tables as experience has shown that significant changes in the level of demand do not take place during intervals of less than 10 to 15 minutes.

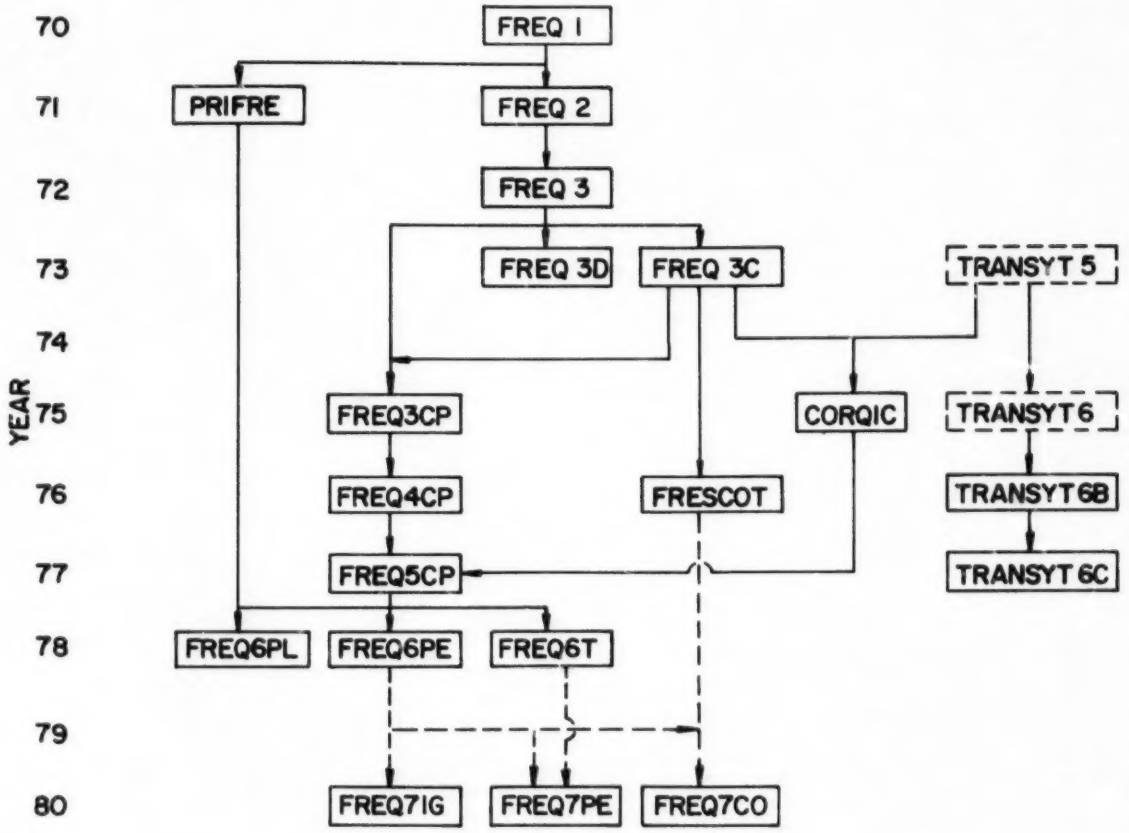


Figure 2.1/ Freeway Corridor and Arterial Network Models

It is also important that the selected time slice have sufficient time for a vehicle to travel the freeway section within one time slice under free flow conditions.

The second type of data for the FREQ7PE model is vehicle occupancy data. This data must be in the form of automobiles with one to three plus occupants and buses. Separate O-D tables may be developed to reflect the different passenger characteristics for each type of vehicle.

The remaining input data requirements for this program are existing freeway characteristics which include capacity, speed flow curves, existing grades, the number of trucks and ramp characteristics such as capacity, left-hand on-ramps, two lane on-ramps and on-ramps merge characteristics (e.g. length of acceleration lane, length of merge lane).

2.3 OUTPUT RESULTS

FREQ7PE corridor simulation model is an operational tool with the output being designed to provide the user with as much or as little detail as needed.

The options in this program give four levels of output choices for each of the six output sequences.

OUTPUT SEQUENCE	OUTPUT LEVEL
1. Input	1. Summary tables or title page
2. Before Control	2. Subsection description tables or delay calculations and performance tables for each time slice
3. After Control	
4. Short Trip Spatial Response	
5. Long Trip Spatial Response	3. Adds metering plan to input tables
6. Modal Response	4. Adds O-D tables as well as travel time and speed flow curves.

The user is also given the option to print mainline delay calculations and contour maps, if desired.

The input sequences are summarized in three tables.

1. Title page which outlines the selected or default options the program will use.
2. Freeway and Arterial Design Features provides a description of each section and includes design speed, origin-destination data, truck factors, special ramp features and arterial characteristics.
3. Distribution of Vehicle Occupancy is a proportion distribution table developed from the input data.

In addition Ramp Limits and Queue Length Limits will be displayed at this time, if provided.

The simulation output format will display:

1. A Freeway Performance Table which details the queuing and delay calculations and displays the congestion intensity on the freeway.
2. An Arterial Performance Table which summarizes, by arterial section, the delay and performance statistics.
3. A Freeway Summary Table which details the calculated freeway delay and performance statistics by time slice.
4. An Arterial Summary Table which details the calculated arterial delay and performance statistics by time slice.

The optimization output formats provides all of the essential information about the metering plan and gives:

1. A Metering Plan Summary Table which includes the metering rate and metering need information and the effective queuing and diversion statistics.
2. A Ramp Control Summary Table which details the metering rate, queued vehicles and diverted vehicles at each ramp.
3. An Optimization Summary Table which summarizes the vehicle and passenger demands by time slice.

Additional output features may be selected by the user to provide more detailed data for performance analysis. These options include plotting of the speed flow curve, O-D tables of demand (original, transferred and diverted) and freeway travel times for each time slice. Finally a set of contour maps can be selected which illustrate freeway speed and queue contours.

3. APPLICATION OF FREQ7PE SIMULATION PROGRAM

3.1 PROJECT LIMITS

The specific purpose of this undertaking was to carry out an evaluation of FREQ7PE's capability to simulate the actual conditions being experienced on eastbound Q.E.W., from west of the Highway 403/Ford Drive off-ramps and the start of the Q.E.W. express/collector system east of the Highway 427 on-ramp during the morning peak period. These project limits were selected for the following reasons:

1. The limits encompass the existing Q.E.W. freeway traffic management system.
2. The limits include the section of the Q.E.W. which is experiencing the greatest congestion during the morning peak period.
3. It is the section of freeway within the Toronto area where the greatest amount of input data is readily available.

Since the primary purpose of the project was to evaluate the programs capability to simulate the freeway operation characteristics, the undertaking was not extended to include the investigation and evaluation of the existing or future arterial street simulation, the emission and fuel consumption capabilities of the modelling program or the ramp metering and diversion strategies.

3.2 DESCRIPTION OF OPERATING ENVIRONMENT

The Q.E.W. study section is located primarily in the City of Mississauga and is the major commuting route for the residents who live west of Toronto and work in Metropolitan Toronto. The Q.E.W.

eastbound study section begins just west of the Highway 403/Ford Drive off-ramp and ends just east of the Highway 427 southbound to Q.E.W. eastbound on-ramps, a total distance of 18.8 kilometres.

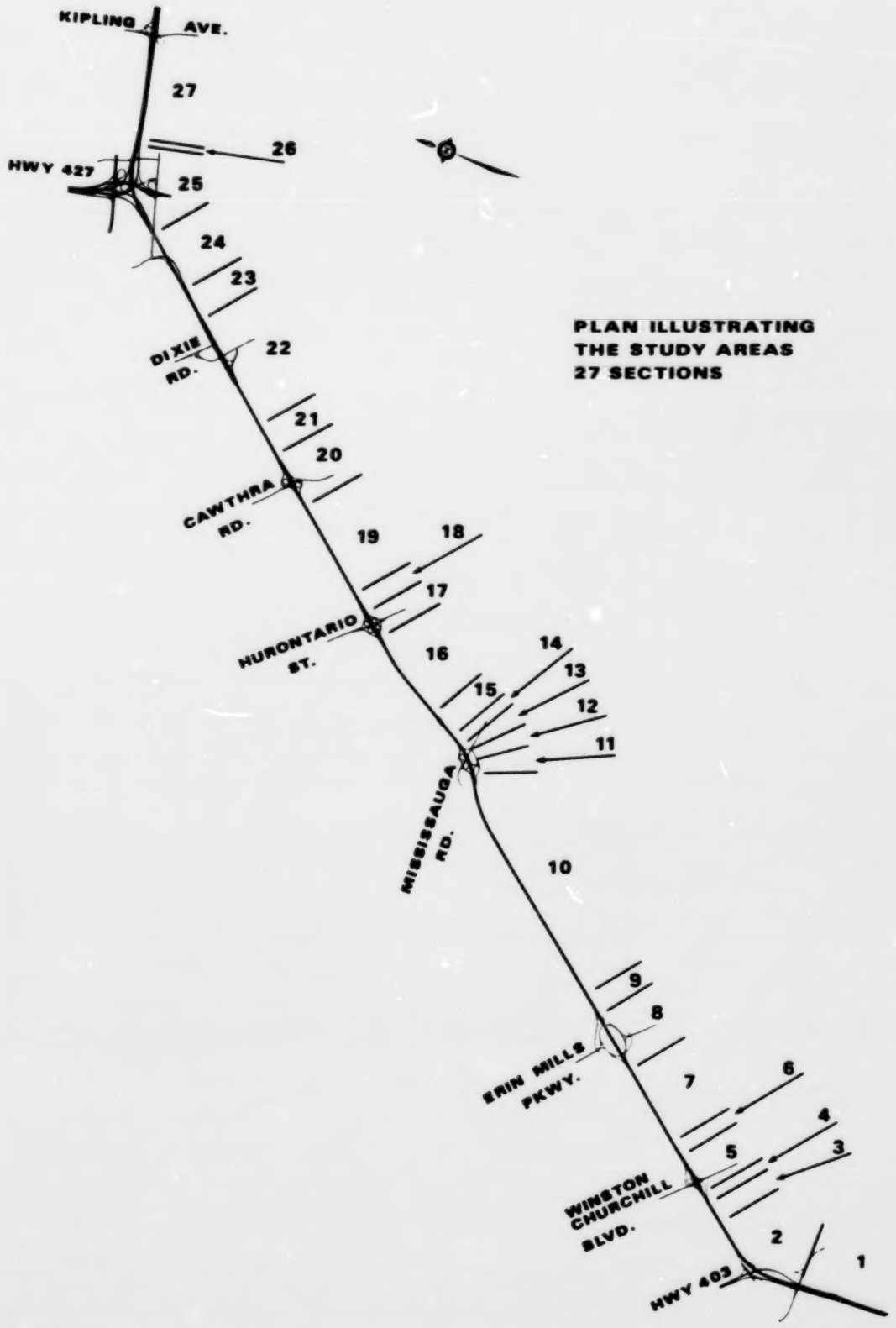
In regard to geometric conditions in the study section, the Q.E.W. begins as a 3-3.65 metre lane section west of Hwy. 403 and ends as a 5-3.65 metre lane section east of Highway 427. Along the freeway study section there is a total of 27 sections with 10 origin inputs including the mainline origin in the first section and 9 destination outputs including the mainline exit in the last section. All on-ramps are right side single lane ramps except for the Highway 427 southbound to Q.E.W. eastbound ramp which is a 2 lane on-ramp. The off-ramps are all right side single lane ramps except for the Highway 403/Ford Drive and Highway 427 ramps which are right side 2 lane ramps.

At the present time the existing F.T.M.S. system regulates the following eastbound on-ramp traffic during the morning peak period.

- Ford Drive
- Winston Churchill Boulevard
- Erin Mills Parkway/Southdown Road
- Mississauga Road
- Hurontario Street
- Cawthra Road

3.3 INPUT DATA

The input data required for the model are of two major types: freeway facility data and freeway demand data.



PLAN ILLUSTRATING
THE STUDY AREAS
27 SECTIONS

Figure 3.0/

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FREQ7PE

PAGE 2

FREQ7PE: MTC VERSION
ALEX UGGE (416)248-3355

FREEWAY AND ARTERIAL DESIGN FEATURES

SUB SEC	NO. LNS	SSEC CAP	SSEC LENGTH	DESIGN SPEED	ORG DES	TRK FAC	SSEC GRAD	PCT TRK	PCT DES TRUCKS	SPECIAL RAMP	FF.SPD. ALT.RTE	CAP. ALT.RTE	ART TYPE	GRADE ALT.RTE	SUBSECTION LOCATION
1	3	6000.	970.	1 *	OD	0.95	0.5	5	0	NO	0.0	0.	GOOD	0.0	403 OFF RAMP
2	3	6000.	4500.	1 *		0.83	1.6	5	0	NO	0.0	0.	GOOD	0.0	
3	3	5800.	880.	1 *	D	0.74	2.9	5	0	NO	0.0	0.	GOOD	0.0	403 ON RAMP
4	3	6000.	105.	1 *	D	0.74	2.9	5	0	NO	0.0	0.	GOOD	0.0	W.C.B OFF
5	3	6000.	2315.	1 *		0.95	0.4	5	0	NO	0.0	0.	GOOD	0.0	
6	3	5800.	760.	1 *	O	0.95	-0.2	5	0	NO	0.0	0.	GOOD	0.0	W.C.B. ON
7	3	6000.	3915.	1 *	D	0.95	-1.1	5	0	NO	0.0	0.	GOOD	0.0	ERIN MILLS OFF
8	3	6000.	2150.	1 *		0.95	-0.2	5	0	NO	0.0	0.	GOOD	0.0	
9	3	5800.	900.	1 *	O	0.95	-1.3	5	0	NO	0.0	0.	GOOD	0.0	ERIN MILLS ON
10	3	6000.	10715.	1 *	D	0.95	-0.8	5	0	NO	0.0	0.	GOOD	0.0	MISSISSAUGA OFF
11	3	6000.	525.	1 *		0.95	-0.3	5	0	NO	0.0	0.	GOOD	0.0	
12	3	5800.	145.	1 *	O	0.95	-0.3	5	0	NO	0.0	0.	GOOD	0.0	MISSISSAUGA ON
13	3	6000.	585.	1 *		0.95	-0.3	5	0	NO	0.0	0.	GOOD	0.0	
14	3	5800.	720.	1 *	O	0.95	-0.3	5	0	NO	0.0	0.	GOOD	0.0	MISSISSAUGA ON
15	3	5400.	1000.	1 *		0.95	-0.3	5	0	NO	0.0	0.	GOOD	0.0	CREDIT RIV BR
16	3	6000.	3730.	1 *	D	0.95	-0.3	5	0	NO	0.0	0.	GOOD	0.0	HWY 10 OFF
17	3	6000.	1385.	1 *		0.95	0.9	5	0	NO	0.0	0.	GOOD	0.0	
18	3	5800.	750.	1 *	O	0.95	-1.4	5	0	NO	0.0	0.	GOOD	0.0	HWY 10 ON
19	3	6000.	5145.	1 *	D	0.95	0.2	5	0	NO	0.0	0.	GOOD	0.0	CAWTHRA OFF
20	3	6000.	2100.	1 *		0.95	0.3	5	0	NO	0.0	0.	GOOD	0.0	
21	3	5800.	1200.	1 *	O	0.95	0.0	5	0	NO	0.0	0.	GOOD	0.0	CAWTHRA ON
22	3	6000.	5360.	1 *		0.95	0.1	5	0	NO	0.0	0.	GOOD	0.0	
23	4	7700.	1835.	1 *	OD	0.95	-1.3	5	0	NO	0.0	0.	GOOD	0.0	DIX ON EVANS OF
24	4	8000.	2970.	1 *	D	0.95	1.1	5	0	2 LN	0.0	0.	GOOD	0.0	427 OFF
25	3	6000.	3475.	1 *		0.95	0.3	5	0	NO	0.0	0.	GOOD	0.0	
26	5	9300.	90.	1 *	D	0.95	0.8	5	0	2 LN	0.0	0.	GOOD	0.0	427 ON
27	5	9500.	3305.	1 *	D	0.95	-0.3	5	0	NO	0.0	0.	GOOD	0.0	MAINLINE QEW

* INDICATES USER-SUPPLIED SPEED-FLOW CURVE NUMBER

Figure 3.1/

A computer listing of the freeway facility data is shown in Figure 3.1. The 18.8 km study section was divided into 27 subsections with boundaries between subsections identifying locations where changes in traffic demand, capacity or gradient occurred.

The flow of eastbound traffic may be interpreted as flowing down the page (Figure 3.1) from subsection 1 to subsection 27. The remaining freeway facility data may be illustrated by subsection 19 which begins at the end of the Hurontario Street (Highway 10) on-ramp and ends at the Cawthra Road off-ramp. This subsection is 3 lanes wide, has a capacity 6,000 vehicles per hour, is 5,145 feet (1,568 metres) long. The 1 with an "*" indicates a user-supplied design speed-flow curve which is illustrated in Figure 3.2. There is a destination (off-ramp) at the end of the subsection and the truck factor which is calculated by the program from the grade and truck percentages is 0.95. The average gradient for this section is +0.2% and the average percentage of trucks is 5 with an assumed 0% of the trucks being diesel. There are no special ramps (e.g. 2 lane on-ramps or left side on-ramps) in this section.

No data was input for the next four columns, since the information required here is for alternate routes which are not being simulated in this project.

The last column indicates by significant feature (e.g. ramps, bridges, etc.) where the subsections are located.

The freeway demand data consists of origin-destination tables and passenger vehicle occupancy distribution.

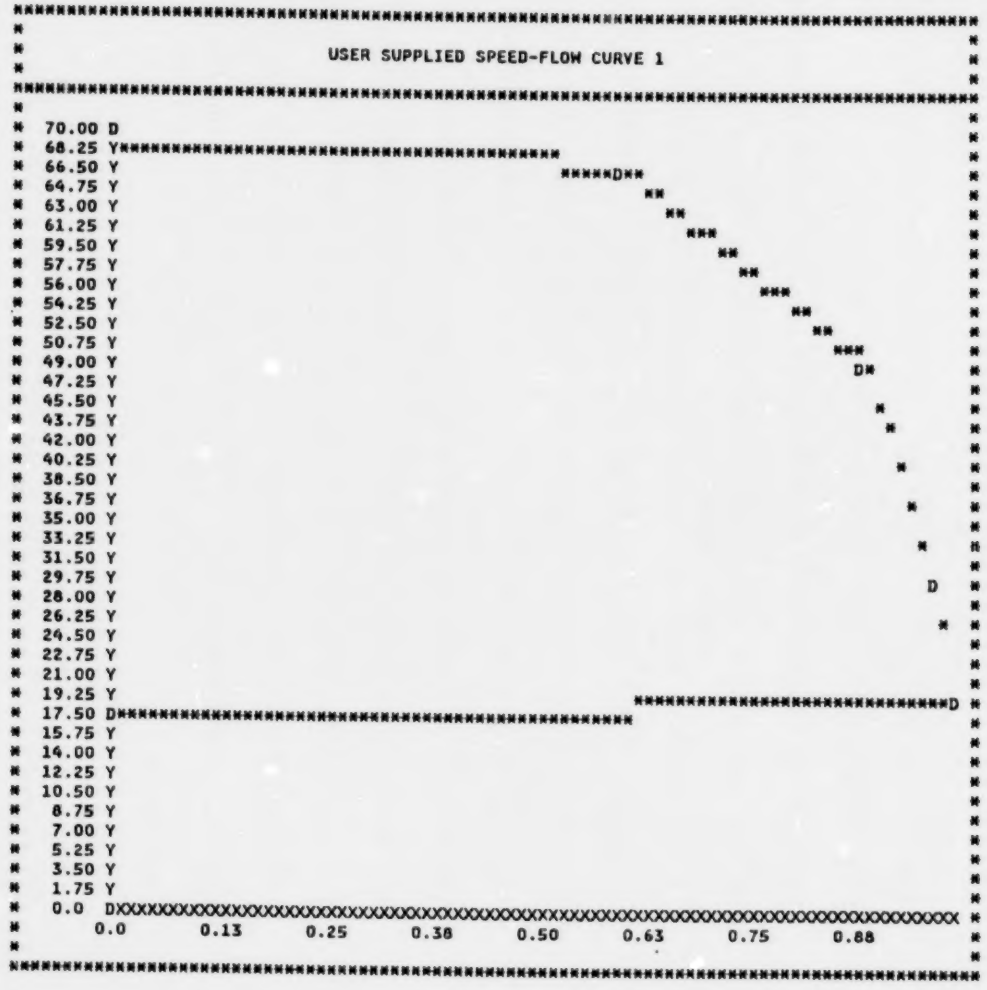
USER SUPPLIED SPEED-FLOW CURVE 1
70.00 D
68.25 Y
66.50 Y
64.75 Y
63.00 Y
61.25 Y
59.50 Y
57.75 Y
56.00 Y
54.25 Y
52.50 Y
50.75 Y
49.00 Y
47.25 Y
45.50 Y
43.75 Y
42.00 Y
40.25 Y
38.50 Y
36.75 Y
35.00 Y
33.25 Y
31.50 Y
29.75 Y
28.00 Y
26.25 Y
24.50 Y
22.75 Y
21.00 Y
19.25 Y
17.50 D
15.75 Y
14.00 Y
12.25 Y
10.50 Y
8.75 Y
7.00 Y
5.25 Y
3.50 Y
1.75 Y
0.0 D
0.0
0.13
0.25
0.38
0.50
0.63
0.75
0.88

Figure 3.2/

The study section was analyzed for the morning peak period from 6:00 a.m. to 9:00 a.m. Fifteen minute time slices were selected for analysis, resulting in 12 time slices being documented. Since the amount of bus traffic on this route during the morning rush hour is negligible only one origin-destination table was prepared for all vehicles for each time slice. A sample origin-destination table for all vehicles in the 7th time slice is shown in Figure 3.3.

A distribution of vehicle occupancy table was developed (Figure 3.4) for all vehicles and was applied to all ramps for all time slices.

3.4 ENTRY CONTROL

The FREQ7PE's entry control and diversion options were not investigated as the purpose of this undertaking was to only ascertain the simulation capability of this program.

3.5 VEHICULAR NOISE AND EMISSIONS

The FREQ7PE's option of estimating the impact of noise and emissions was not investigated as the purpose of this undertaking was to only ascertain how well this program would simulate the existing traffic flow characteristics of the eastbound lanes of the Q.E.W. during the morning peak period.

3.6 OUTPUT DATA

For this project the output data that was investigated to determine the ability of the model to simulate the existing Q.E.W. conditions, included the freeway performance table, the freeway summary table and the contour diagram of speed.

ALL CARS

ORIGINS DOWN	DESTINATIONS ACROSS 1	2	3	4	5	6	7	8	9	SUM
1	1580	340	84	32	184	92	200	532	1052	4096
2	0	80	20	8	44	24	48	128	252	604
3	0	0	24	8	48	24	52	136	272	564
4	0	0	0	16	96	48	104	276	544	1084
5	0	0	0	0	60	32	64	176	348	680
6	0	0	0	0	60	32	68	176	352	688
7	0	0	0	0	0	48	104	284	560	996
8	0	0	0	0	0	0	68	184	364	616
9	0	0	0	0	0	0	224	596	1180	2000
10	0	0	0	0	0	0	0	0	3992	3992
SUM	1580	420	128	64	492	300	932	2488	8916	15320

ORIGINAL DEMANDS ARE ACTUAL COUNTS NOT HOURLY RATES

Figure 3.3/

DISTRIBUTION OF VEHICLE OCCUPANCY

ON RAMP NUMBER	PASSENGERS PER VEHICLE 1	2	3 OR MORE	BUSES	AVERAGE CARPOOL (3+) OCCUPANCY	AVERAGE BUS OCCUPANCY
1	0.800	0.150	0.050	0.0	0.0	0.
2	0.800	0.150	0.050	0.0	0.0	0.
3	0.800	0.150	0.050	0.0	0.0	0.
4	0.800	0.150	0.050	0.0	0.0	0.
5	0.800	0.150	0.050	0.0	0.0	0.
6	0.800	0.150	0.050	0.0	0.0	0.
7	0.800	0.150	0.050	0.0	0.0	0.
8	0.800	0.150	0.050	0.0	0.0	0.
9	0.800	0.150	0.050	0.0	0.0	0.
10	0.800	0.150	0.050	0.0	0.0	0.

ON-RAMP LOCATIONS 1 3 6 9 12 14 18 21 23 26

OFF-RAMP LOCATIONS 1 4 7 10 16 19 23 24 27

ORIGINAL DEMANDS ARE ACTUAL COUNTS NOT HOURLY RATES

Figure 3.4/

A copy of the computer print out for the freeway performance table is shown in Figure 3.5. While the first three columns repeat the input characteristics of each subsection, the next six columns summarize the origin-destination demands and resulting adjusted volumes. The next two columns indicate each subsection capacity and weave effect (the theoretical subsection capacity is reduced by the calculated weave effect).

The queue length and storage rate columns indicate the simulated congestion that is taking place on the facility. This congestion is also illustrated by the V/C ratio column which increases from a low of 0.42 to a maximum of 1.0 (the start of the queuing) and the speed in mph which decreases from a maximum of 69 mph to a low of 20 mph.

The remaining four columns of output data summarizes the results of the energy and emission analysis.

A computer listing of the freeway summary table is shown in Figure 3.6. The summary data are presented for each time slice along with grand totals for each category.

The contour diagram of speed in mph is illustrated in Figure 3.7 and illustrates the simulated congestion that is occurring on the freeway in a graphical format with the duration of the congestion being shown on the vertical (time slice) axis and extent of the delay being portrayed by the horizontal axis (subsection lengths).

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FREQ7PE
SIMULATION BEFORE ENTRY CONTROL
TIME SLICE 7 OF 12

FREQ7PE: HTC VERSION
ALEX UGGE (416)248-3355

QUEUE COLLISION IN SECTION 18 T2 =0.029

FREEWAY PERFORMANCE TABLE

SUB SEC	NO. LNS	SSEC LENGTH	O-D DATA DEMANDS ORG.	DES.	ADJUSTED VOLUMES DEM.	ORG.	DES.	FRNY VOL.	CAP.	WEAVE EFF	QUEUE LENGTH	STORAGE RATE	V/C	SPEED MPH	FUEL MPG	HC GS/VH	CO GS/VH	NOX GS/VH
1	3	970.	4096.	1580.	4096.	4096.	1580.	4096.	6000.	0.	0.	0.	0.68	63.	13.67	2.45	11.62	3.42
2	3	4500.	0.	0.	2516.	0.	0.	2516.	6000.	0.	0.	0.	0.42	69.	11.37	2.27	9.73	3.74
3	3	880.	604.	0.	3120.	604.	0.	3120.	5800.	0.	0.	0.	0.54	68.	10.13	2.28	9.87	3.72
4	3	105.	0.	420.	3120.	0.	420.	3120.	6000.	0.	0.	0.	0.52	68.	10.13	2.28	9.85	3.72
5	3	2315.	0.	0.	2700.	0.	0.	2700.	6000.	0.	0.	0.	0.45	69.	14.71	2.27	9.77	3.73
6	3	760.	564.	0.	3264.	564.	0.	3264.	6000.	0.	0.	0.	0.56	68.	14.78	2.28	9.89	3.71
7	3	3915.	0.	128.	3264.	0.	128.	3264.	6000.	0.	0.	0.	0.54	68.	14.77	2.28	9.87	3.72
8	3	2150.	0.	0.	3136.	0.	0.	3136.	6000.	0.	0.	0.	0.52	68.	14.75	2.28	9.85	3.72
9	3	900.	1084.	0.	4220.	1080.	0.	4216.	5800.	0.	0.	0.	0.73	60.	16.41	2.53	12.53	3.26
10	3	10715.	0.	64.	4220.	0.	64.	4096.	6000.	0.	* 705.	120.	0.68	59.	16.06	2.53	12.52	3.32
11	3	525.	0.	0.	4156.	0.	0.	4032.	6000.	0.	** 525.	120.	0.67	21.	15.45	4.23	32.31	2.29
12	3	145.	680.	0.	4836.	680.	0.	4712.	5800.	0.	** 145.	120.	0.81	20.	15.71	4.48	35.21	2.12
13	3	585.	0.	0.	4836.	0.	0.	4712.	6000.	0.	** 585.	120.	0.79	20.	15.64	4.49	35.31	2.12
14	3	720.	688.	0.	5524.	688.	0.	5400.	5800.	0.	** 720.	120.	0.93	20.	16.00	4.45	34.77	2.13
15	3	1000.	0.	0.	5524.	0.	0.	5400.	5400.	0.	0.	0.	1.00	20.	16.18	4.42	34.51	2.13
16	3	3730.	0.	492.	5524.	0.	481.	4958.	6000.	0.	* 3629.	442.	0.83	30.	17.13	3.54	23.99	2.51
17	3	1385.	0.	0.	5032.	0.	0.	4477.	6000.	0.	** 1385.	442.	0.75	21.	13.45	4.34	33.52	2.19
18	3	750.	996.	0.	6028.	996.	0.	5473.	5800.	0.	** 750.	327.	0.94	20.	16.06	4.44	34.69	2.13
19	3	5145.	0.	300.	6028.	0.	289.	5473.	6000.	0.	** 5145.	327.	0.91	20.	15.99	4.44	34.72	2.13
20	3	2100.	0.	0.	5728.	0.	0.	5184.	6000.	0.	** 2100.	327.	0.86	20.	15.83	4.47	35.02	2.12
21	3	1200.	616.	0.	6344.	616.	0.	5800.	5800.	0.	0.	0.	1.00	20.	16.18	4.42	34.51	2.13
22	3	5360.	0.	0.	6344.	0.	0.	5800.	6000.	0.	0.	0.	0.97	33.	21.60	3.33	21.00	2.47
23	4	1835.	2000.	932.	8344.	1750.	841.	7550.	7700.	0.	0.	0.	0.98	30.	21.90	3.55	23.61	2.40
24	4	2970.	0.	2488.	7412.	0.	2246.	6709.	8000.	0.	0.	0.	0.84	54.	15.32	2.82	15.42	2.91
25	3	3475.	0.	0.	4924.	0.	0.	4463.	6000.	0.	0.	0.	0.74	59.	16.62	2.58	12.98	3.20
26	5	90.	3992.	0.	8916.	3500.	0.	7963.	9300.	0.	0.	0.	0.86	53.	15.50	2.83	15.60	2.87
27	5	3305.	0.	8916.	8916.	0.	7963.	7963.	9500.	0.	0.	0.	0.84	54.	17.68	2.82	15.41	2.91
TOTAL		61530.										MAX(V/C) = 1.00 AVG = 36.			16.26	3.20	20.14	2.83

* INDICATES MAINLINE QUEUES (ALL LANES)
M INDICATES MERGE QUEUES (RIGHT MOST LANE)
B INDICATES MAINLINE AND MERGE QUEUES

Figure 3.5/

FREEWAY SUMMARY TABLE
SIMULATION BEFORE CONTROL

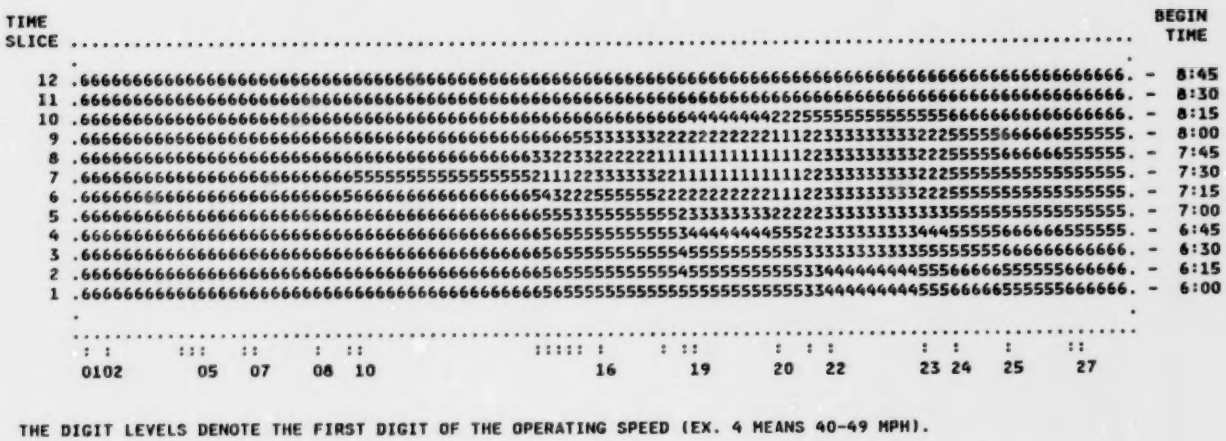
TIME SLICE	FREEWAY TRAVEL TIME VEH-HR	FREEWAY TRAVEL TIME PAS-HR	RAMP DELAY VEH-HR	RAMP DELAY PAS-HR	TOTAL FREEWAY TRAVEL TIME VEH-HR	TOTAL FREEWAY TRAVEL TIME PAS-HR	TOTAL TRAVEL DISTANCE VEH-MI	TOTAL TRAVEL DISTANCE PAS-MI	AVERAGE SPEED MPH	GASOLINE CONSUMED GALLONS	HYDROCARB EMISSIONS KILOGRAMS	CARBON MONOXIDE KILOGRAMS	NITROUS OXIDES KILOGRAMS	BEGIN TIME
1	232.	255.	0.	0.	232.	255.	13045.	14350.	56.3	814.	34.	173.	42.	6:00
2	233.	256.	0.	0.	233.	256.	13059.	14364.	56.1	812.	34.	174.	42.	6:15
3	237.	261.	0.	0.	237.	261.	13038.	14342.	55.0	805.	34.	177.	41.	6:30
4	261.	287.	0.	0.	261.	287.	13296.	14626.	51.0	809.	36.	194.	41.	6:45
5	305.	335.	0.	0.	305.	335.	13829.	15211.	45.4	816.	40.	224.	41.	7:00
6	362.	398.	17.	19.	379.	417.	14306.	15737.	39.5	865.	45.	279.	41.	7:15
7	391.	430.	57.	63.	448.	493.	13904.	15295.	35.6	886.	49.	333.	40.	7:30
8	374.	412.	94.	103.	468.	515.	13038.	14342.	34.8	863.	49.	351.	38.	7:45
9	314.	345.	127.	139.	440.	484.	11940.	13134.	38.1	817.	47.	339.	36.	8:00
10	153.	169.	161.	177.	314.	345.	8947.	9842.	58.4	687.	35.	258.	32.	8:15
11	90.	98.	160.	175.	249.	274.	6145.	6760.	68.7	518.	27.	207.	24.	8:30
12	75.	82.	144.	158.	219.	240.	5138.	5652.	68.8	438.	23.	183.	20.	8:45
TOTAL	3025.	3327.	759.	835.	3784.	4162.	139686.	153655.	46.2	9130.	454.	2890.	439.	

***** TOTAL MAINLINE DELAY (VEH-HRS) ***** DESIRED SPEED = 55.0 *****

TIME SLICE	DELAY	TIME SLICE	DELAY	TIME SLICE	DELAY	TIME SLICE	DELAY	TIME SLICE	DELAY

Figure 3.6/

CONTOUR DIAGRAM OF
SPEED
BEFORE OPTIMIZATION



THE DIGIT LEVELS DENOTE THE FIRST DIGIT OF THE OPERATING SPEED (EX. 4 MEANS 40-49 MPH).

Figure 3.7/

3.7 EVALUATION OF COMPUTER RUNS

In total 43 computer simulation runs of the FREQ7PE program were made for the eastbound study section of the Q.E.W. in an effort to achieve the best possible approximation of the existing contour diagram of speed which was developed as part of the Q.E.W. Freeway Traffic Management System study. Figure 3.8 lists the computer runs, the key input data, the purpose of the run and the results of our review of the output data.

A sample contour diagram of speed in km/h has been included in this section as Figure 3.9 with the copies of all of the contour diagrams in km/h being included in Appendix A of this report. For illustrative purposes a number "6" in the contour diagram of speed represents 51 to 60 km/h . The isochronal speed chart that was developed for the Q.E.W. Freeway Traffic Management System Study from field speed runs has been superimposed on all of the contour diagrams of speed to illustrate the reasonableness of each simulation.

It should be noted that the other output data provided by this program (e.g. queue length and storage rate) have not been analyzed because we did not have sufficient existing data available to undertake a comparison.

The first 9 computer simulations were undertaken using the program supplied speed flow curve while changing the capacity, the design speed and weaving methodology. The next 18 simulations were undertaken to determine the effect that a system specific speed flow curve would have on the contour diagram of speed when combined with various capacity and design speed changes and weaving methodology.

FIGURE 3.8 (a) - SUMMARY OF COMPUTER RUNS AND THE PURPOSE FOR UNDERTAKING EACH RUN

Run ID	Weave Type	WAFs		No of Sect	Design Speed mph	Capacities				S/F Curve	PURPOSE	RESULTS
		Pre-427	427 Off			Thru	Thru and Ramp	Pre-427	427 Off			
1	-	-	-	27	65	5250	6150	7000	7000	-	Initial computer run.	Speeds are too high in free flow and too low after breakdown queues are long and slow.
2	L TRB	1.0	1.0	27	65	6000	6900	7750	7750	-	Increase the capacity of all sections to 6000, decrease the speeds at the 427 off ramp by introducing weaving.	Long, very slow queue as V/C = 1.0 in Evans off ramp section. Speeds are fast in most early time slices from high capacity.
3	-	-	-	27	65	6000	6900	7750	7750	-	Increase the capacity of all subsections to 6000. No weaving effects.	Very minor queuing and high speeds. Queues start in correct subsections.
4	L HCM	1.0	1.0	27	65	6000	6900	7750	7750	-	Try a different weaving method.	Slightly slower queues than TRB methods.
5	HCM HCM	0.5	0.5	27	75	5700	6900	7400	7400	-	Introduce a higher design speed to increase the free flow speed and analyse a different weaving combination.	Queuing occurred in later time slices due to high weave effect. Free flow speeds were slower even with higher design speed.
6	HCM HCM	0.5	0.5	27	70	5700	6900	7400	7400	-	Analyse the effects of design speed on the free flow traffic speeds.	Speeds identical to 75 mph design speed.
7	HCM HCM	0.5	0.5	27	65	5700	6900	7400	7400	-	Analyse the effects of design speed on the free flow traffic speeds.	Speeds faster than 70 or 75 mph design.
8	HCM HCM	0.5	0.5	27	60	5700	6900	7400	7400	-	Analyse the effects of design speed on the free flow traffic speeds.	Speeds slower than 70 or 75 mph design speed.
9	HCM HCM	0.5	0.5	27	55	5700	6900	7400	7400	-	Analyse the effects of design speed on the free flow traffic speeds.	Speeds faster than 60 mph and slower than 70 design speed.

Weave Methodology

L
TRB - Leisch curves, T.R.B. circular 212 distribution methods (presegregated)

L
HCM - Leisch curves, H.C.M. proportional volume distribution

HCM
HCM - H.C.M. curves, H.C.M. proportional volume distribution

HCM
TRB - H.C.M. curves, T.R.B. circular 212 distribution methods (presegregated)

WAF - Weave Adjustment Factor (weave effect calculation method)

S/F - "-" Computer Supplied - "1 to 5" User Supplied

FIGURE 3.8 (b) - SUMMARY OF COMPUTER RUNS AND THE PURPOSE FOR UNDERTAKING EACH RUN

Run ID	Weave Type	WAFs		No of Sect	Design Speed mph	Capacities				S/F Curve	PURPOSE	RESULTS
		Pre-427	427 Off			Thru	Thru and Ramp	Pre-427	427 Off			
10	HCM HCM	1.0	1.0	27	-	6000	6900	7750	7750	1	Develop higher free flow and queue speeds using own speed flow curve with HCM and HCM weaving.	Low queue speeds and short queues (to sect 15).
11	HCM TRB	1.0	1.0	27	-	6000	6900	7750	7750	1	Use HCM and TRB weaving.	Slightly longer queues with TRB weaving methods and slower queue speeds.
12	HCM HCM	1.0	1.0	27	-	6000	6900	7750	6250	1	Reduce capacity in the East End Cr. Riv Br. section and the 427 off ramp section to reduce the speed in these sections.	Slower speeds at 427 off ramp section and queues are still too short in general (to sect 15).
13	HCM HCM	1.0	1.0	27	-	6000	6900	8000	6200	1	Increase capacity in the section preceeding the 427 off ramp to prevent queuing in these sections.	Queues are shorter and start from the wrong subsections in later time slices (from 427 off).
14	HCM HCM	1.0	1.0	27	-	6000	6900	7750	6300	1	Increase 427 off capacity to prevent queuing in later time slices.	This didn't work as the queue still starts from the 427 off in later time slices. Queues from pre-427 in earlier slices.
15	HCM HCM	1.0	1.0	27	-	6000	6900	7750	6400	1	Increase capacity in 427 off ramp section to prevent V/C = 1.0 in this section.	Still queuing from 427 off in later time slices.
16	HCM HCM	1.0	1.0	27	-	6000	6900	8000	6400	1	Increase speeds in the pre-427 off ramp sections to show increase in speeds before 427 off ramp.	Speeds in sections preceeding 427 off are faster but not as fast as 427 off ramp section.
17	HCM HCM	0.5	0.5	27	-	6000	6900	8000	6400	1	Reduce the capacity at the Cr Riv Br to cause a queue in section 15.	Queuing in section 15 causes smaller queues around the 427. There are higher speeds over all.

Weave Methodology

L
TRB - Leisch curves, T.R.B. circular 212 distribution methods (presegregated)

L
HCM - Leisch curves, H.C.M. proportional volume distribution

HCM
HCM - H.C.M. curves, H.C.M. proportional volume distribution

HCM
TRB - H.C.M. curves, T.R.B. circular 212 distribution methods (presegregated)

WAF - Weave Adjustment Factor (weave effect calculation method)

S/F - "-" Computer Supplied - "1 to 5" User Supplied

FIGURE 3.8 (c) - SUMMARY OF COMPUTER RUNS AND THE PURPOSE FOR UNDERTAKING EACH RUN

Run ID	Weave Type	WAFs		No of Sect	Design Speed mph	Capacities				S/F Curve	PURPOSE	RESULTS
		Pre-427	427 Off			Thru	Thru and Ramp	Pre-427	427 Off			
18	HCM HCM	1.0	1.0	27	-	6000	6900	8000	6400	1	Change WAF to 1.0.	No difference from 17.
19	HCM HCM	1.0	1.0	28	-	6000	6900	8300	6400	1	Add new section for Cr River Br with reduced capacity, and increase capacity at pre-427 sections.	Pre-427 speed is higher but all queues preceeding the 427 area are too short.
20	HCM	1.0	1.0	28	-	6000	6900	8400	6400	1	Increase pre-427 capacities to 8400 to get increased speeds.	Queues from 427 area too short, and V/C = 1.0 at the 427 in later time slices.
21	HCM HCM	1.0	1.0	27	-	6000	6900	8000	6400	1	Combine the pre-427 subsections into one subsection.	Same results as with 2 subsections.
22	HCM TRB	1.0	1.0	27	-	6000	6900	8000	8000	1	Increase capacity at 427 off ramp section.	Weave calc puts emphasis on right subsections so no reduction in capacity is needed at the 427 off ramp section.
23	HCM HCM	1.0	1.0	27	-	6000	6900	8000	6400	1	Eliminate 4-lane sections at on ramps, using HCM methods and 6400 capacity at 427 weave section.	Slighting longer recovery period for queue, but no major differences.
24	HCM TRB	1.0	1.0	27	-	6000	6900	8000	8000	1	Eliminate 4-lane sections using TRB methods and 8000 capacity at 427 weave section.	Same as 22 - no change due to elimination of the 4 lane on ramp sections to 3 lanes.
25	HCM TRB	1.0	0.5	27	-	6000	6000	8000	6400	1	Reduce weave effects with WAFs because TRB methods do not require a reduced capacity in the weave section (test weaves).	No change due to reduced weave effect. Need modifications to the program.

Weave Methodology

L
TRB - Leisch curves, T.R.B. circular 212 distribution methods (presegregated)

L
HCM - Leisch curves, H.C.M. proportional volume distribution

HCM
HCM - H.C.M. curves, H.C.M. proportional volume distribution

HCM
TRB - H.C.M. curves, T.R.B. circular 212 distribution methods (presegregated)

WAF - Weave Adjustment Factor (weave effect calculation method)

S/F - "-" Computer Supplied - "1 to 5" User Supplied

FIGURE 3.8 (d) - SUMMARY OF COMPUTER RUNS AND THE PURPOSE FOR UNDERTAKING EACH RUN

Run ID	Weave Type	WAFs Pre-427	WAFs 427 Off	No of Sect	Design Speed mph	Capacities Thru	Capacities Thru and Ramp	Capacities Pre-427	Capacities 427 Off	S/F Curve	PURPOSE	RESULTS
26	HCM TRB	1.0	1.0	27	-	6000	6000	8000	8000	1	Program correction for WAFs.	Queuing in pre-427 off section which should be faster than the 427 off ramp section.
27	HCM TRB	1.0	1.0	27	-	6000	6000	8000	8000	1	Test WAF corrections.	
28	HCM TRB	0.5	1.0	27	-	6000	6000	8000	8000	2	Reduce WAF to 0.5 in pre-427 section.	Speed is slightly slower in pre-427 off than at 427 off, and the queues are too short.
29	-	-	-	27	-	5800	5800	7700	7800	2	Eliminate weaving and try to find the best capacity before introducing weaving effects.	Queues are approaching the correct length but are still a little short.
30	-	-	-	27	-	5800	5800	7800	7900	2	Increase capacity to test for capacity sensitivity.	Speeds are slightly higher in some sections due to increased capacity.
31	-	-	-	27	-	6000	5800	7700	8000	3	For the s/f curve try to establish an operating capacity.	Queue length is too short and speeds are too high. The pre-427 speed is too low.
32	HCM TRB	.01	0.5	27	-	6000	5800	8000	8000	3	Increase pre-427 capacity and do not allow high weaving effect in this section, in order to maintain high speeds.	Queue length is still too short.
33	HCM TRB	.01	0.55	27	-	6000	5800	7700	8000	3	Increase weave effect at 427 off ramp section.	Speeds in 427 weave section are too high in early time slices, but develop queues in middle time slice.

Weave Methodology

L
TRB - Leisch curves, T.R.B. circular 212 distribution methods (presegregated)

L
HCM - Leisch curves, H.C.M. proportional volume distribution

HCM
HCM - H.C.M. curves, H.C.M. proportional volume distribution

HCM
TRB - H.C.M. curves, T.R.B. circular 212 distribution methods (presegregated)

WAF - Weave Adjustment Factor (weave effect calculation method)

S/F - "-" Computer Supplied - "1 to 5" User Supplied

FIGURE 3.8 (e) - SUMMARY OF COMPUTER RUNS AND THE PURPOSE FOR UNDERTAKING EACH RUN

Run ID	Weave Type	WAFs		No of Sect	Design Speed mph	Capacities				S/F Curve	PURPOSE	RESULTS
		Pre-427	427 Off			Thru	Thru and Ramp	Pre-427	427 Off			
34	HCM TRB	.01	0.5	27	-	6000	5800	7700	8000	3	Run the 32 results in km/hr.	Same results as 32.
35	-	-	-	27	-	6000	6000	7700	8000	4	Try to establish an operating capacity.	Queuing from wrong section and queues are too short.
36	-	-	-	27	-	6000	5800	7700	8000	4	Reduce capacities to increase queue length.	Queuing from wrong section and queues are too short.
37	-	-	-	27	-	5800	5800	7500	7700	4	Reduce capacities to increase queue length.	Ques not starting early enough.
38	-	-	-	27	-	5800	5600	7300	7700	4	Reduce capacities to increase queue length.	Better approximation of existing conditions.
39	HCM TRB	.01	0.5	27	-	5800	5600	7500	7600	4	Introduce weaving.	Queues may be too long.
40	HCM TRB	.01	0.5	27	-	5700	5500	7500	7400	4	Reduce capacities to increase queue length.	Queues are approaching the correct length, but the pre-427 off ramp section speed is too low.
41	-	-	-	27	-	6000	6000	7700	8000	5	Analyze the effect of capacities on free flow traffic speeds.	Operating speeds are high.
42	-	-	-	27	-	5800	5800	7500	7700	5	Analyze the effect of capacities on free flow traffic speeds.	Operating speed too low in sections 1 to 8.
43	-	-	-	27	-	6000	5800	7700	8000	5	Analyze the effect of capacities on free flow traffic speeds.	Operating speed too high in sections 16 to 23.

Weave Methodology

L
TRB - Leisch curves, T.R.B. circular 212 distribution methods (presegregated)

L
HCM - Leisch curves, H.C.M. proportional volume distribution

HCM
HCM - H.C.M. curves, H.C.M. proportional volume distribution

HCM
TRB - H.C.M. curves, T.R.B. circular 212 distribution methods (presegregated)

WAF - Weave Adjustment Factor (weave effect calculation method)

S/F - "-" Computer Supplied - "1 to 5" User Supplied

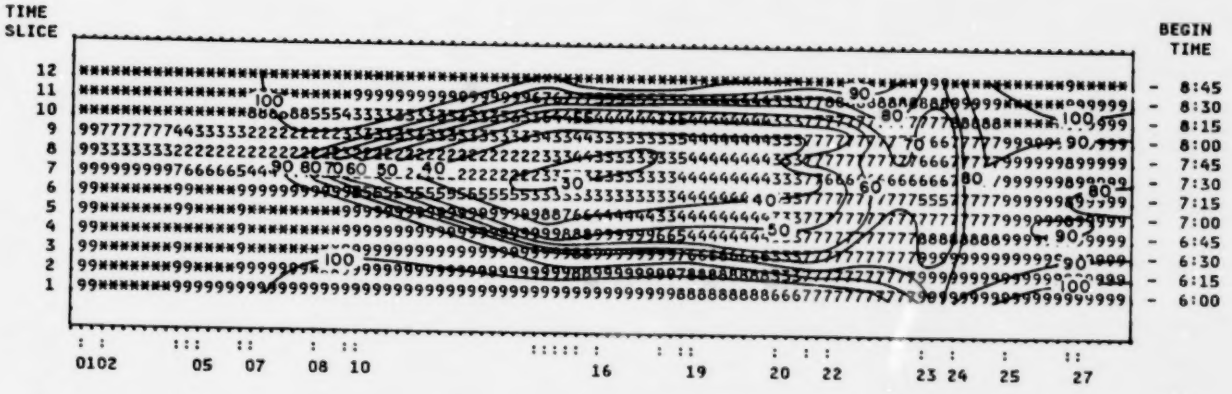
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

FREQ7PE

PAGE

FREQ7PE: MTC VERSION
ALEX UGGE (416)248-3355

CONTOUR DIAGRAM OF
SPEED (KM/H)
BEFORE OPTIMIZATION



NOTE--THE DIAGRAM VALUES ARE NORMALIZED TO LIE IN THE RANGE 0-10 (WHERE ASTERISK DENOTES 10).

Figure 3.9/

The last 16 computer simulation runs included combining various speed flow curves with different capacities and weave effects.

4. SUMMARY

In summary and based on our experience with this program on this project, we concluded that the FREQ7PE freeway simulation program is capable of providing a reasonable approximation of the existing operating speeds that are being experienced on the eastbound section of the Q.E.W. between the Highway 403 and Ford Drive off-ramps and the start of the collector distributor system east of Highway 427. Since existing queue length and storage rate data was not available we are unable to comment on the simulation accuracy of the other output data.

In addition to the foregoing, we have prepared the following list of general comments in regard to our experience with the FREQ7PE freeway simulation program.

- The documentation of the program and the input data requirements are excellent and as a result no difficulties were encountered in undertaking the simulation program. However, while the output data appears adequate, there is very little documentation or explanation available to assist in the calibration of the model or in the interpretation and analysis of the output tables.

- A major advantage of this program is the fact that each computer run requires less than 30 seconds of computer time and as a result cost less than $10.00 per run. Therefore, the greatest

cost associated with using this program would be the collection of the input data to permit the proper calibration of the program.

- During this project, we found that the program is very sensitive to the speed flow curves used. We would, therefore, recommend that one or more speed flow curves be developed for the facility being simulated. In addition, our analysis of the speed flow data collected for the Q.E.W. indicated that the operating speed of the traffic recovering from congestion, did not follow the historical speed flow curve pattern. We are of the opinion that this change in recovery speed characteristics, which we were unable to simulate in a speed flow curve, may be a major contributor in the low speeds that are being simulated downstream from the known point of congestion.

- Based on our simulations the contour diagram of speed appears to be fairly sensitive to the input design speed.

- The simulation program did not appear to be very sensitive to the inclusion of the additional acceleration lanes that exist at all on-ramp locations.

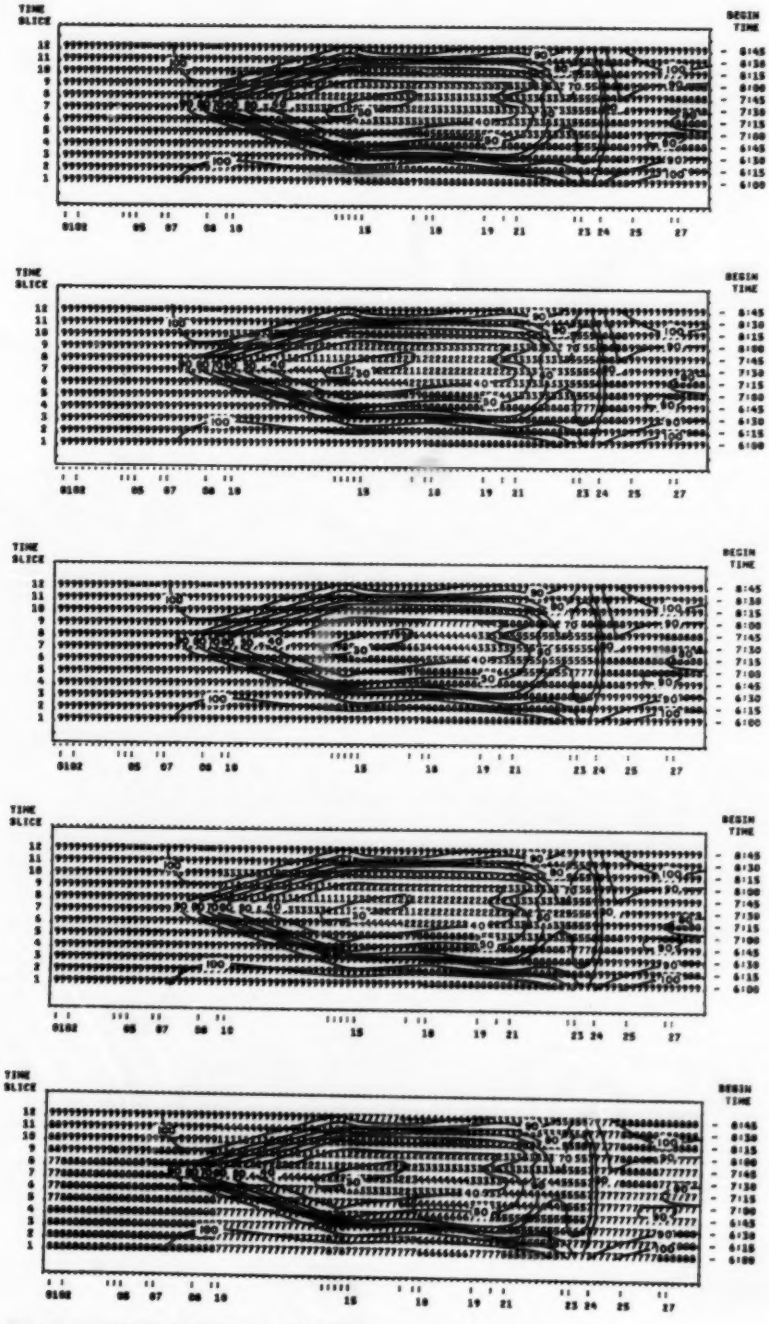
- The Highway Capacity Manual weave calculation appeared to more accurately simulate the operating conditions on the Q.E.W. than the combination of the Leisch curves with either the H.C.M. proportional volume distribution or T.R.B. circular 212 distribution method with presegregation.

In general, and based on project specific experience with the FREQ7PE freeway simulation program, we are of the opinion that this program appears to be a good method of simulating freeway operating conditions.

APPENDIX

CONTOUR DIAGRAMS OF SPEED

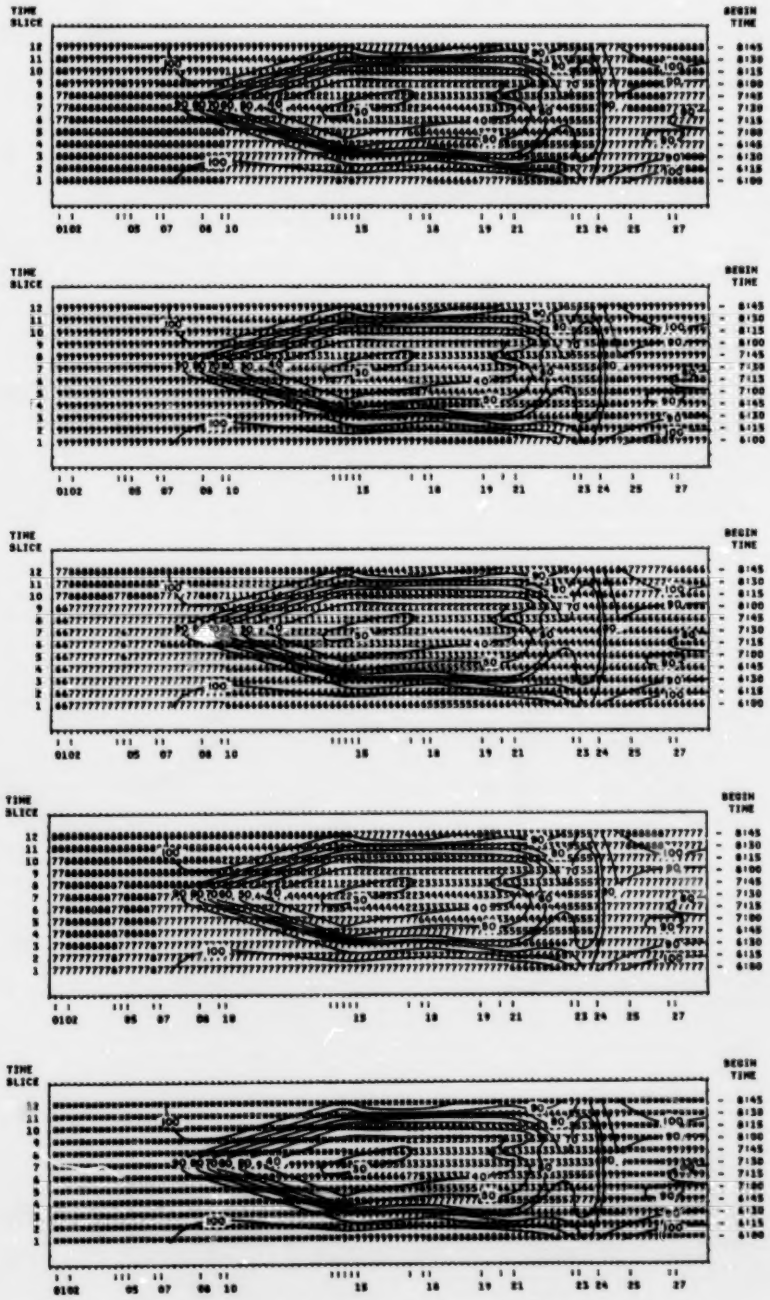
CONTOUR DIAGRAM OF
SPEED (KM/H.)
BEFORE OPTIMIZATION



NOTE--THE DIAGRAM VALUES ARE NORMALIZED TO LIE IN THE RANGE 0-10 (WHERE ASTERISK DENOTES 10).

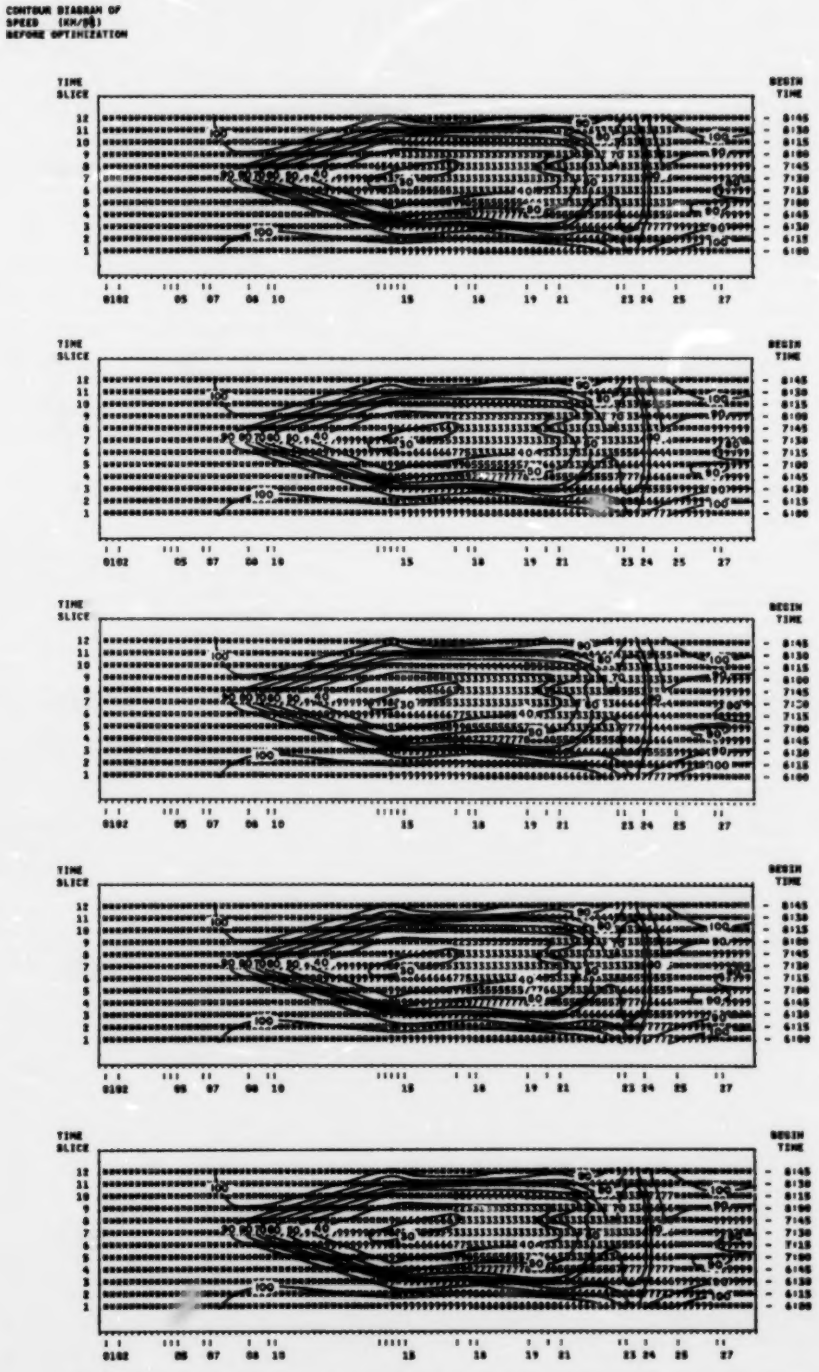
FREQ7PE Generated Contour Diagrams of Speed (km/h)

CONTOUR DIAGRAM OF
SPEED (KM/H)
BEFORE OPTIMIZATION

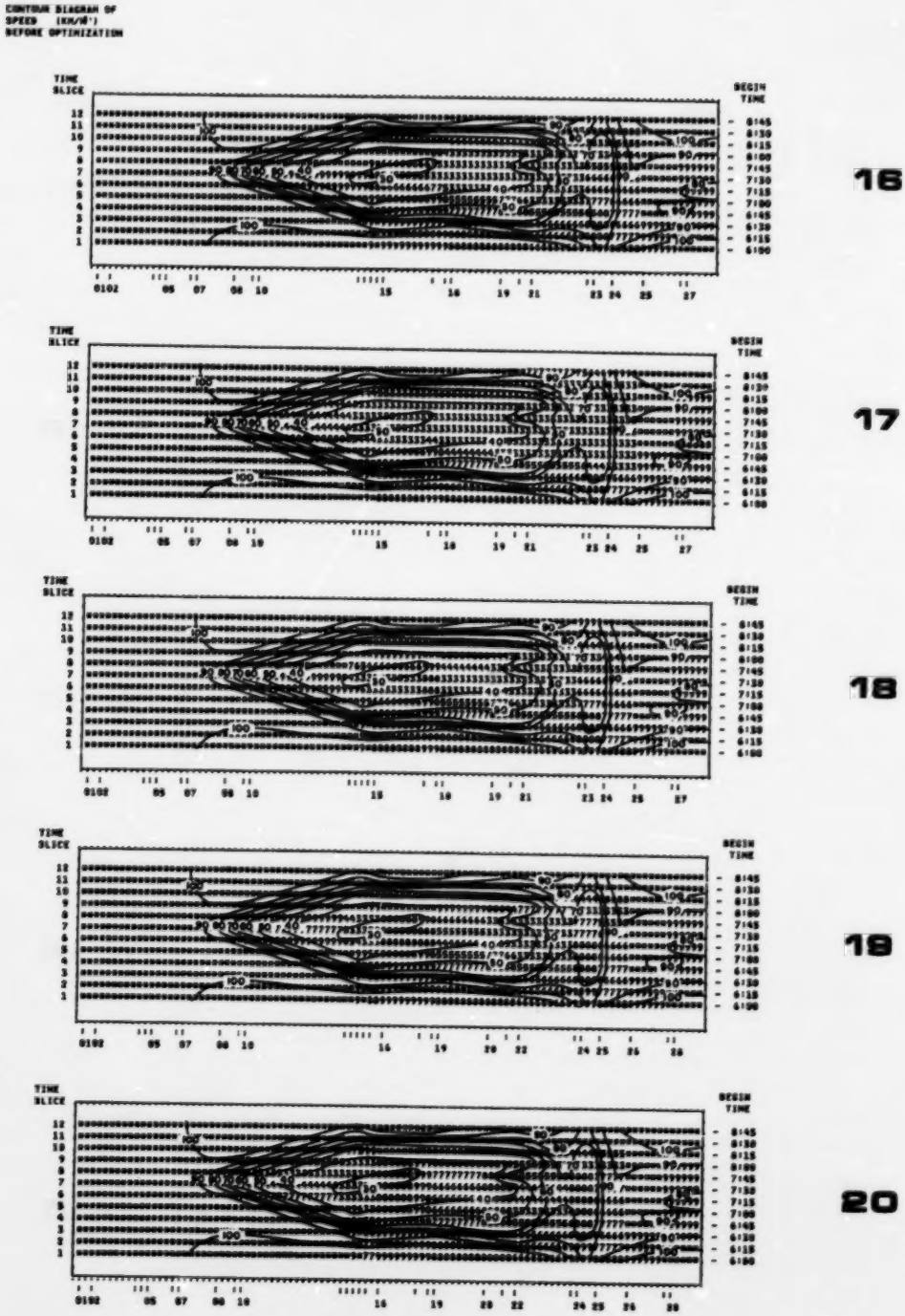


NOTE--THE DIAGRAM VALUES ARE NORMALIZED TO LIE IN THE RANGE 0-10 (WHERE ASTERISK DENOTES 10).

FREQ7PE Generated Contour Diagrams of Speed (km/h)

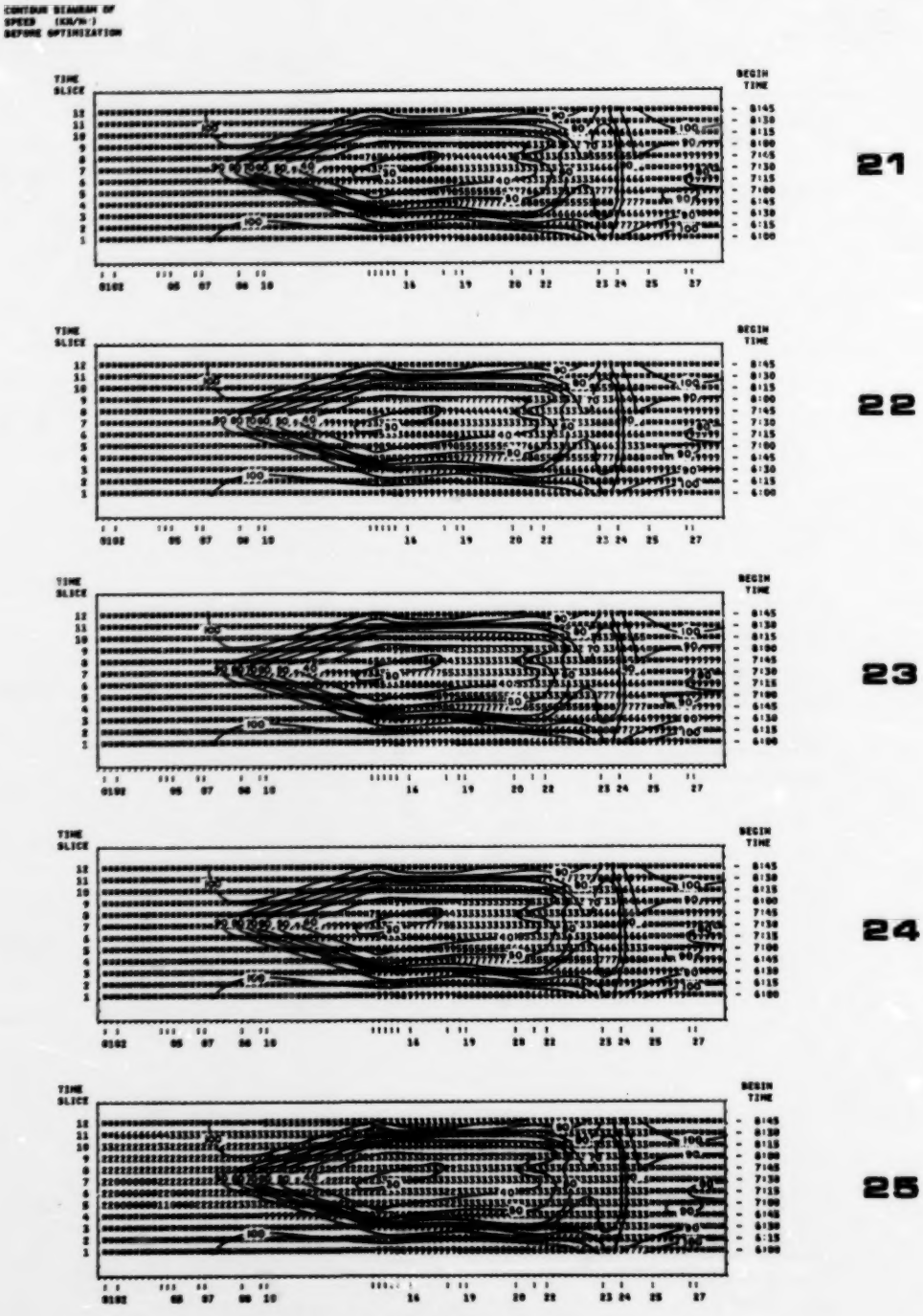


FREQ7PE Generated Contour Diagrams of Speed (km/h)



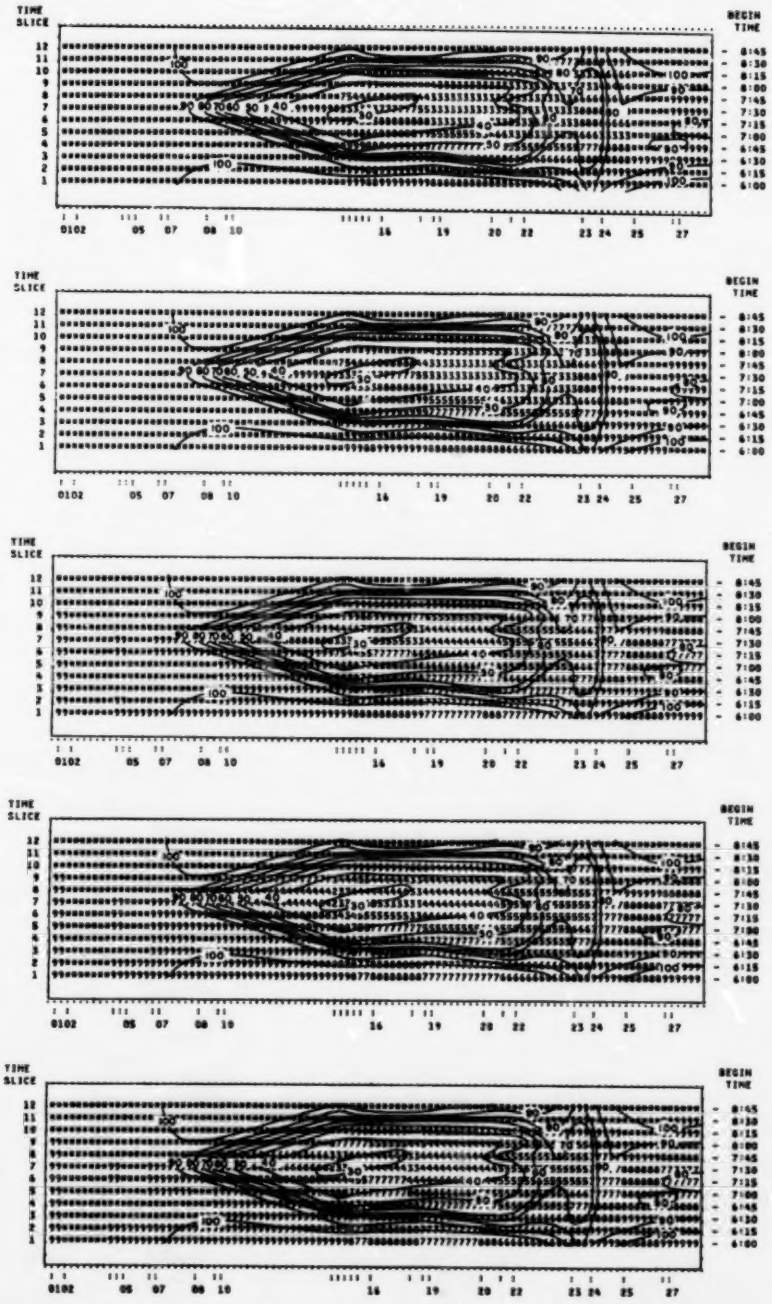
NOTE--THE DIAGRAM VALUES ARE NORMALIZED TO LIE IN THE RANGE 0-10 (WHERE ASTERISK DENOTES 10).

FREQ7PE Generated Contour Diagrams of Speed (km/h)



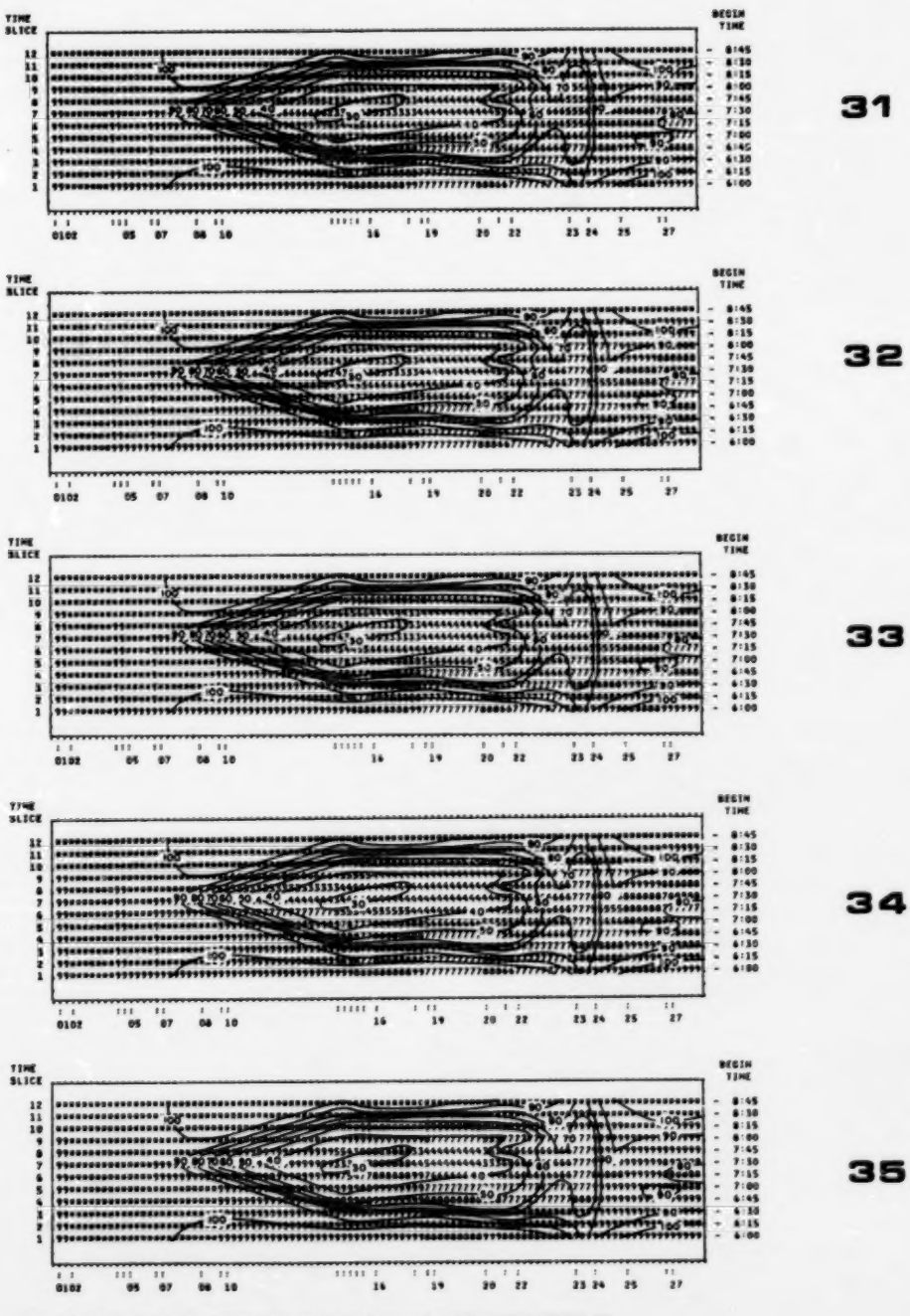
FREQ7PE Generated Contour Diagrams of Speed (km/h)

CONTOUR DIAGRAM OF
SPEED (KM/H)
BEFORE OPTIMIZATION



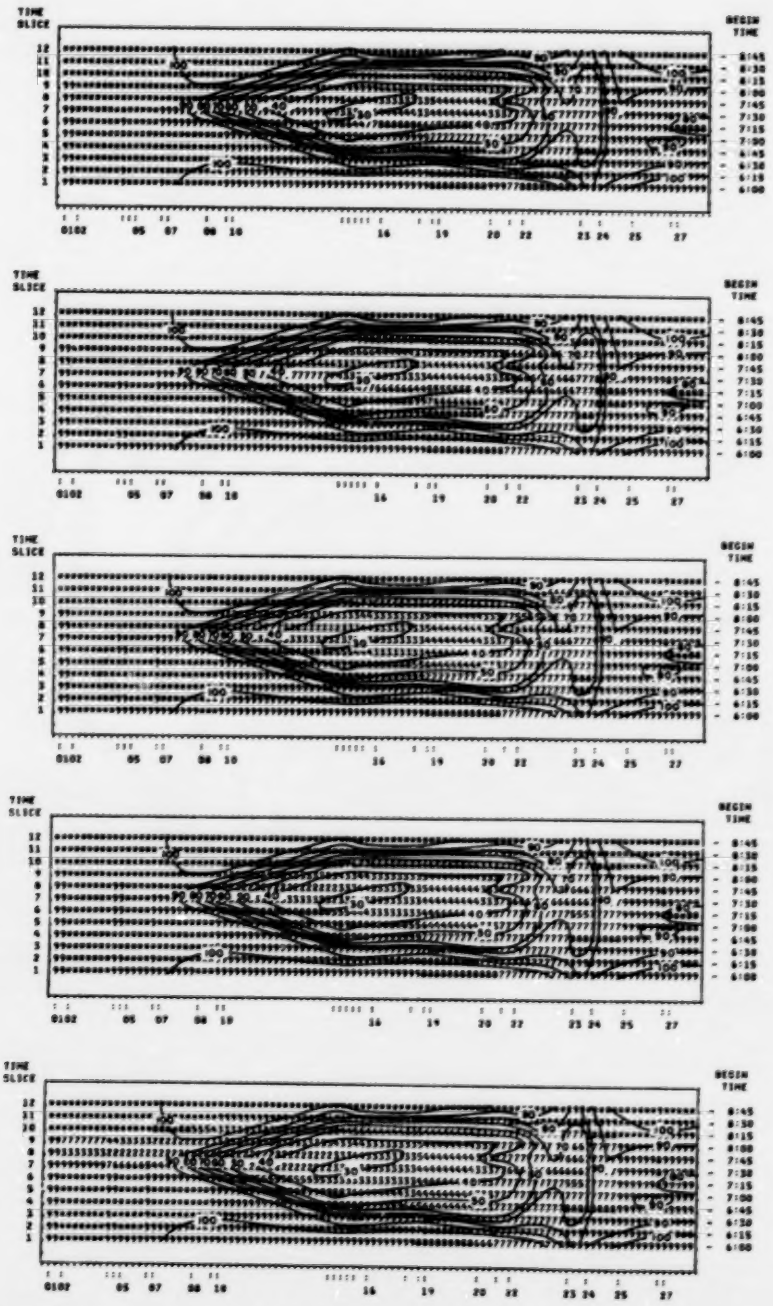
NOTE--THE DIAGRAM VALUES ARE NORMALIZED TO LIE IN THE RANGE 0-10 (WHERE ASTERISK DENOTES 10).

FREQ7PE Generated Contour Diagrams of Speed (km/h)



FREQ7PE Generated Contour Diagrams of Speed (km/h)

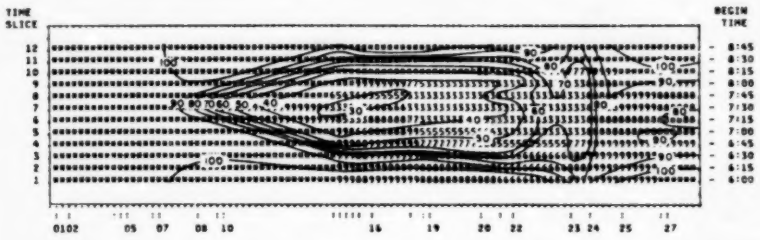
CONTOUR DIAGRAM OF
SPEED (KM/H)
BEFORE OPTIMIZATION



NOTE--THE DIAGRAM VALUES ARE NORMALIZED TO LIE IN THE RANGE 0-10 (WHERE ASTERISK DENOTES 10).

FREQ7PE Generated Contour Diagrams of Speed (km/h)

CONTOUR DIAGRAM OF
SPEED (KM/H)
BEFORE OPTIMIZATION



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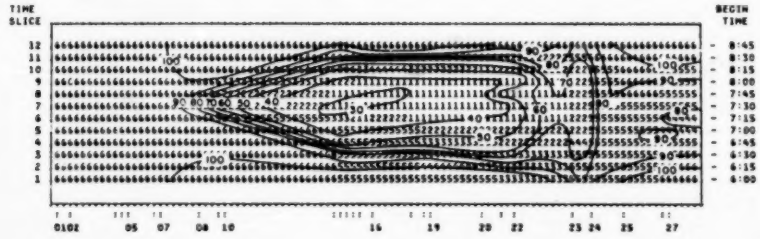
NOTE--THE DIAGRAM VALUES ARE NORMALIZED TO LIE IN THE RANGE 0-10 (WHERE ASTERISK DENOTES 10).

CONTOUR DIAGRAM OF
SPEED
BEFORE OPTIMIZATION



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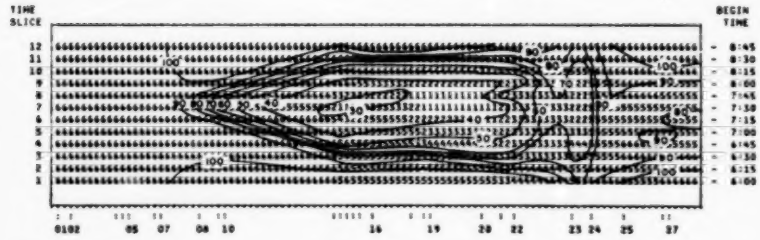

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* THE DIGIT LEVELS DENOTE THE FIRST DIGIT OF THE OPERATING SPEED (EX. 4 MEANS 40-49 MPH).

FREQ7PE Generated Contour Diagrams of Speed (km/h)